VIII.—*On the Tarsus and Carpus of Birds.* (*Plates* IV, V.)

By EDWARD S. MORSE, Ph. D.

Read January 29th, 1872.

Among the many interesting features of structure, common to birds and reptiles, that have been pointed out from time to time by Huxley, Gegenbaur, Dana and others, that point which established the existence of tarsal bones in birds, with the joint occurring between the first and second tarsal series as in reptiles, seems the most important.

There is still, however, a variance of opinion as to the number and condition of the tarsal and carpal bones in birds, and upon this question I hope to throw some little light.

The most important contribution has been made by Gegenbaur,* who has shown the presence of two tarsal bones in the embryo chick, which unite, respectively, with the distal end of the tibia and the proximal end of the metatarsus, leaving the ankle joint between the proximal and distal tarsal series, as in reptiles. In the upper tarsal bone he figures two centres of ossification, and from what he finds in certain reptiles, believes that these two centres in the cartilaginous mass indicate the presence of two tarsal elements, the astragalus and calcaneum.

In referring to other authors, I find a great difference of opinion respecting the existence of any tarsal bones. Prof. Owen, who has contributed so largely to our knowledge of the osteology of birds, particularly the larger and more aberrant forms, such as *Apteryx*, *Dinornis*, *Æpyornis* and

*Untersuchungen zur Vergleichenden Anatomie der Wirbelthiere. Erstes Heft Carpus und Tarsus. Leipzig, 1864.

others, while admitting the existence of three carpal bones, one of which, the *magnum*, unites with the base of the mid-metacarpal, says, in his last work on the Comparative Anatomy of the Vertebrates,* that the tarsus is absent, or perhaps blended with the tibia or metatarsus. In speaking of the term *tarso-metatarse*, as applied by some ornithotomists to the segment sustaining the phalanges, he says it implies the tarsal homology of the epiphysis, and adds that the same might be predicable of the distal epiphysis of the tibia; but neither of these points being demonstrated, he prefers to call that segment the *metatarse*.

Still later, in the year 1869, in a memoir on the Fossil Reptiles of the Liassic Formation,† he strongly insists upon calling the tarsal bones of birds, epiphyses.

Admitting, as Prof. Owen does, the excessive tendency in the skeleton of birds to anchyloses, and further admitting the interesting correspondence between the wing and the leg, in the coalescence of the metacarpals and metatarsals respectively, and also admitting the confluence of the *magnum* with the proximal end of the mid-metacarpal, it seems strange, indeed, that he could not have interpreted the so-called epiphyses of the tibia and metatarsals as true tarsal ossicles; or, having interpreted them as epiphyses, that the same mode of reasoning should not have led him to regard the *magnum* as an epiphysis also.

Mr. W. K. Parker, in a valuable paper on the osteology of *Balæniceps rex*,‡ suggests the existence of a tarsal bone, in describing the tibia of that bird, as follows: "This inferior, or distal end of the tibia is developed from a distinct osseous centre in young birds, which piece forms all the articular parts, and sends upward a wedge-shaped process in front—the seat of the ossification which makes the large, wide, oblique, tendon-like bridge.

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*Vol. II, p. 79. †Palæontographical Soc., Vol. XXIII, part II, p. 77.
‡Zoological Trans., Vol. IV, part 7, 1861.

"Below this bridge the bone is deeply scooped, and the concavity between the condyloid margins of the trochlea is very considerable. Query. Is the lower articular portion of the tibia an epiphysis of the tibia itself, or is it the homologue of the mammalian astragalus?"

Gegenbaur's discoveries confirm the supposition of Mr. Parker, and prove that the term *tarso-metatarsus* is appropriately applied to that segment of the leg bearing the phalanges.

Besides the discovery of Gegenbaur's, above mentioned, of the two tarsal bones and the two centres of ossification in the upper, or proximal one, he recognizes and figures two carpal bones, one corresponding to the radius, the other corresponding to the ulna; these he designates, respectively, the *radiale* and the *ulnare*.

In considering these points, and reflecting upon the character of these bones in the higher classes of vertebrates, it seemed to me that further investigation should reveal more carpal bones in birds; that bones representing the distal carpal series should be present, and that the calcaneum and astragalus should be more clearly demonstrated.

In the land tortoises, the chelonians, monitors, crocodiles and even in the low batrachians, whatever the number of ossicles the carpus and tarsus respectively present, there appear to be at least two ossicles in the first, or proximal series, as in the *pes*, for instance, where there is one corresponding to the tibia, and another corresponding to the fibula.

In the carpus, likewise, according to the demonstrated homology between the fore and hind limbs, we should expect to find other carpal bones anchylosing with the proximal ends of the metacarpals, leaving the joint between the first and second carpal series, as in the tarsus. With no prejudice in favor of these views, nor doubting the observations of others, I yet determined to satisfy myself, and so took up the study of these features, as revealed in the embryonic stages of the class.

Knowing the importance of making many observations upon different species, in order to arrive at any general truth in the matter, I studied the embryos of all the birds at my limited command, and my only regret is, that the species I was able to examine were so few in number, and so similar in character. For this material my thanks are chiefly due to Mr. Frank L. Scribner and Anson Allen, Esq.

The embryos studied were those of the Bank swallow, *Cotyle riparia;* Eave swallow, *Hirundo lunifrons;* Kingbird, *Tyrannus Carolinensis;* Crow blackbird, *Quiscalus versicolor;* Cow blackbird, *Molothrus pecoris;* Bluebird, *Sialia sialis;* Chipping sparrow, *Spizella socialis;* Yellow warbler, *Dendrœca æstiva;* Wilson's thrush, *Turdus fuscescens*, and the Spotted sandpiper, *Tringoides macularius.*

I have no means of determining, with certainty, the age of any of the embryos examined, but have made a careful life-size drawing of each one, so that an approximate idea may be formed of their condition and age.

As all these studies were made from living specimens, more dependence can be placed upon the results obtained, than if they had been drawn from alcoholic specimens, in which the tissues are opaque.

Tarsus. (See plate IV.). In all the embryos examined, there were three distinct bones composing the tarsus. Two of these belonged to the proximal series, one corresponding to the tibia, and the other to the fibula, representing, respectively, the astragalus and calcaneum. (It seems better to use the terms given by Gegenbaur to these bones, as it removes all objection on the score of questionable homologies. The terms *tibiale* and *fibulare* will therefore be applied to these two bones, and *centrale* to the remaining one belonging to the distal series.) The *tibiale* is generally the largest, and in birds, the inner condyle at the distal end of the tibia is usually the largest, which is in accordance with the proportions of the tarsal bone repre-

senting this process. The *fibulare* unites with the *tibiale* at a very early age, there being a sort of hour-glass shaped constriction between them. From their resemblance, at this stage, to a similar bone in *Lœlaps*, as determined by Prof. Cope, the correctness of the term *astragalo-calcaneum*, applied to that bone by him, is confirmed.

The coalescence of these two bones, forms the peculiar bi-condylar trochlea of the distal end of a bird's tibia; a firm joint is thus rendered; for the inner condyloid margins, thus produced, bear against either side of the *centrale*, which early unites with the proximal ends of the metatarsals.

The mid-metatarsal is generally the shortest at the proximal end, and the *centrale* fills up the depression thus made.

In the crow blackbird the proximal end of the mid-metatarsal at an early stage is crowded back by the metatarsals upon each side of it, as is usual in adult birds.* In the same bird the *centrale* is small and round, and unites chiefly with the mid-metatarsal. In the spotted sandpiper, the *centrale* is lozenge-shaped, and caps the three metatarsals. The *tibiale* and *fibulare* unite, forming a symmetrical hour-glass shaped bone.

In the bank swallow and kingbird, the *centrale* is similar in shape to that of the sandpiper, and in like manner caps the metatarsals. In the bluebird, the *centrale* is very large and irregular in shape, and unites first with the second metatarsal, but overlaps the others. In the yellow warbler the *centrale* is very large and irregular in shape, presenting two conspicuous prominences upon its articular face. In the eave swallow, the *centrale* unites with the metatarsus a long time before the *tibiale* and *fibulare* have united with each other, or with the tibia.

In all the birds examined, the *tibiale* and *fibulare*, with one exception, anchylose together before they unite with the

*See Owen, immature *Dinornis crassus*. Trans. Zool. Soc., VI. pl. 6, and Dr. R. O. Cunningham's *Rhea Darwinii*, Proc. Zool. Soc., 1871, pl. 6. figs. 7 and 8.

tibia. This exception occurs in the kingbird, where these two bones appear to unite with the tibia first, leaving a deep intercondylar groove between them.

Carpus. (See plate v.) In the fore limb or wing there are at least four carpal bones, two in the proximal series, and two in the distal series. When more than four carpals occur, as in the yellow warbler, and possibly in the kingbird, the extra one is found on the radial side, and this seems to be in accordance with what obtains in the higher vertebrates, where we find on the radial side three carpals; the *scaphoid*, *trapezoid* and *trapezium*.

In the proximal series of carpal bones, the *scaphoid* or *radiale* is the largest, and is the first bone to appear in the development of the carpus. This bone is always free.

The cuneiform or *ulnare* is smaller, and in most of the species examined is found beyond the outer edge of the ulna.

In Wilson's thrush, the bank swallow and yellow warbler, it seems to anchylose with the outer distal end of the ulna, so closely is it appressed to that region. On consulting Dr. Elliott Coues in regard to the subject, he informed me that two free carpals are always present in the adult yellow warbler. As this bird when embryonic has an extra carpal present on the radial side, it may be this one with the *radiale* that makes up the two free carpals, yet observations are very limited in this respect; and until the contrary is proved, I shall hold that the *ulnare* may unite with the ulna.

In the distal carpal series is a bone which appears next in development. Whether this represents the *intermedium* and *centrale*, connate, or the third *carpale* (*magnum*), I am not able to say. It is always found at the base of the mid-metacarpal, to which it early anchyloses. This bone is quite small, and lenticular in shape in Wilson's thrush, the chipping sparrow, crow blackbird, eave swallow, bank swallow, kingbird and yellow warbler, and large in the cow blackbird and bluebird.

In the kingbird an accessary carpal is seen near the third

carpale, from which it seems to have separated, fig. 47, plate V. As I found it in no other specimen, it may have been the result of accidental pressure in examination.

The other bone in the distal series may be regarded as the unciform, or *fourth carpale* of Gegenbaur's nomenclature.

This is the last carpal bone to appear in development, though it often attains as large a size as the *third carpale*. This anchyloses almost simultaneously with the base of the *annularis* metacarpal, the *third carpale* and the approximate surface of the mid-metacarpal. The *third* and *fourth carpale* are seen united, by a cartilaginous band, at an early stage in the chipping sparrow and Wilson's thrush. In the cow blackbird the two distal carpals unite before they have joined their respective metacarpals.

In one specimen of kingbird examined, there appeared to be a second carpal just beyond the *radiale*, and similar to that in form; as it was not seen in another specimen, it is safe to reject its occurrence at present.

A very curious shape is assumed by the *ulnare* in the kingbird, bluebird, and cow blackbird, as will be seen by referring to the plate.

With the accompanying figures, which I have endeavored to render faithfully on stone, from my original drawings, further description of these bones is unnecessary. Many other points of interest have come up in this investigation, regarding other peculiarities of the leg and wing, but a discussion of such features would be outside the intended limits of this paper.

The general results of this paper have been submitted to Prof. Jeffries Wyman and Dr. Elliott Coues, U. S. A., and my thanks are due to these gentlemen for their careful consideration of the results therein presented. With Dr. Coues, I had the pleasure of dissecting the tarsus and carpus of an adult penguin, *Aptenodytes Pennantii*, and of examining the same parts of other birds.

Prof. Wyman has generously placed at my disposal the tarsus of an embryo heron, with other specimens of the same bird, and authorized me to embody their peculiar features in this paper. Accompanying the specimens, the following letter was received, which I have the liberty of publishing:

Dear Prof. Morse,—

In a recent examination of the bones of the leg of some unfledged herons (supposed to be *Ardea cærulea*) with reference to their ossification, to which I was led by your admirable embryological studies of the limbs of birds, I found a bone accompanying the groove on the front of the lower end of the tibia, which does not agree with any description of these parts I have seen. It is a style-shaped bone, ends in a sharp point above, has the lower end, which is on a level with the lower end of the tibia, blunt and rounded, and almost exactly resembles, in the older specimens, the fibula of the same leg inverted.

It is about one-fifth as long as the tibia, and as appears from several specimens of different ages, grows, for a time at least, in proportion to the other parts.

In the older specimens two nodules of bone are seen, side by side, in the cartilage part below the tibia, one corresponding to each condyle, as you have pointed out in other birds. These belong to the near portion of the tarsus, and may therefore be supposed to represent the astragalus and calcaneum. Thus we have these two bones entirely apart from the pretibial bone described above.

As regards the homology of this last named piece, the most natural supposition is that it is the ascending process of the astragalus to which attention has of late been called by Huxley and Cope, in discussing the affinities of birds and Dinosaurian reptiles.

Its mode of development, however, leads to the belief that it is not, properly speaking, a process of either of the tarsal bones, but a distinct bone, for it not only has an independent ossification, but is already far advanced in this process, before the ossification of either of the tarsal bones is begun. It has occurred to me that the part in question might have been originally the lower portion of the fibula, from which it had become detached by absorption, but it has not at any time been observed to be continuous with this bone, and further, it continues to grow from below upward, as the young bird gets older, instead of becoming shorter and shorter, as it ought, if this supposition was true.

Observations are now wanted to show whether the ascending process of the astragalus, as seen in the ostrich and other birds, is really an outgrowth from, and therefore a process of, one of the tarsal bones, or whether it ossifies independently, and subsequently becomes united with it. Should this last supposition be decided in the affirmative, then we

should have either a third bone in the leg, which would be contrary to all analogy, or a third member of the near tarsal series, which would, so to speak, be out of place.

Truly yours,

J. WYMAN.

Cambridge, Dec. 20, 1871.

I have examined with the greatest interest, this new tarsal bone of the heron, and from the specimens kindly loaned me by Prof. Wyman, have made the following drawings. The figures represent different stages of the tibia, from the front, with the pretibial bone at the base.

Figure 1 is magnified, the natural size of the tibia being represented by a line at its side. Figures 2, 3 and 4 are natural size.

In referring to Huxley's figures of the tibia of the young ostrich,* and of the young fowl,† I find the so-called process of the astragalus, on the outer side of the tibia, occupying the same region as that of the pretibial bone of the heron, and this leads me to believe that this so-called process of the astragalus in the birds just mentioned, is identical with the pretibial bone of Wyman. ‡

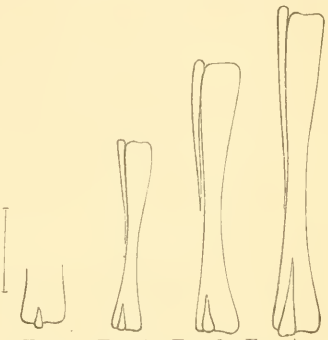

FIG. 1. FIG. 2. FIG. 3. FIG. 4.
The style shaped bone at lower end of tibia represents *intermedium*, or pretibial bone of Wyman.

* Quarterly Jour. Geological Soc., Vol. XXVI, part I, p. 30.

† Anat. Vert. Animals, Huxley, p. 296.

‡ Since writing the above, I have received from Prof. Wyman the distal portion of a tibia from a still older specimen of the blue heron. Accompanying the specimen he writes, "This bird had not left the nest, notwithstanding its large size. You will see the pretibial piece coössified with the astragalus and calcaneum, though neither of them is consolidated with the tibia. There is nothing *now* in this specimen to show that the ascending portion was ever free from the astragalus."

We herewith give a figure of it in section, natural size (Fig. 5); see next page. This removes all doubt as to the relation of the pretibial bone, with the so-called process of the young fowl and young ostrich alluded to above, and leads to the belief that the tendon-like bridge, spanning the groove in front, originates from this piece, as stated by Parker. He also speaks of this process in *Balæniceps rex* as forming "the seat of the ossification which makes the large wide oblique tendon-like bridge. Prof. Wyman informs me that the two are not identical."

It surely is not the distal end of the fibula, for in the larger specimen of tibia examined (fig. 4) I find, with the aid of a hand lens, a delicate tendinous thread running from the lower end of the fibula and the upper end of the pretibial bone, and passing each other, showing no sign of approximation. Furthermore, in all the embryo birds I have thus far examined (see plate IV), the fibula shows no signs of torsion. Dismissing the idea that it represents a third bone of the leg, "as contrary to all analogy," we have only to admit that it represents a new tarsal bone of the proximal series.

FIG. 5.

The specimen represented in figure 1, was sent to me by Prof. Wyman sometime before he had examined the other bones with reference to this new tarsal. In this specimen the metatarsals are still separate, and the presence of the three tarsal bones thus far described is but dimly made out; yet the pretibial bone is quite distinct, and of much importance is the fact that its lower edge is below the lower edge of the tibia. Satisfied that it is a true tarsal bone, to what bone in the tarsus shall we compare it?

After studying over it very carefully, and comparing it with figures of certain amphibians, given by Gegenbaur, and with some of my own drawings of the tarsus of the common wood salamander, *Plethodon erythronotus*, I believe it to represent the *intermedium* of Gegenbaur. In the tarsus of *Salamandra maculosa*, as given by Gegenbaur, the *intermedium* is represented as a much elongated bone, broader at the bottom, and wedged between the tibia and fibula, half of it being actually above the distal margins of these two bones. Above the reptiles, the *intermedium* is supposed by Gegenbaur to coalesce with the *tibiale* or astragalus.

In other words the astragalus represents the *intermedium* and *tibiale*, connate. Gegenbaur believes that the astragalus represents the *scaphoid* and *lunare* of the carpus. In

some mammalia these two latter bones are connate, *e. g.*, in the carnivora; while in others they are free.

The position of this pretibial bone appears anomalous, but when we consider the remarkable displacement of other bones in the bird's leg, the occurrence of this new tarsal in such a place, is by no means unreasonable. The displacement of certain bones in the bird's leg, is the result, as it were, of lateral compression, or rather lateral contraction. The fibula is always reduced to a mere splint bone, and is closely appressed to the tibia. The metatarsals are so crowded together that the proximal end of the mid-metatarsal is forced back, so that the flanking metatarsals actually meet in front. All these ultimately anchylose and form a single bone. The first metatarsal is reduced to a half, or a third the size of the others, and is often crowded behind the others. The two proximal tarsal bones at first, stand one at the end of the tibia, and the other at the end of the fibula, the *tibiale* being actually as wide as the distal end of the tibia (see plate IV, fig. 1); yet in a short time these two tarsal bones are gradually brought together, and as the fibula becomes reduced in comparative size, the tibia takes on an accelerated growth, so that its distal end equals in width the two tarsals to which it finally unites.

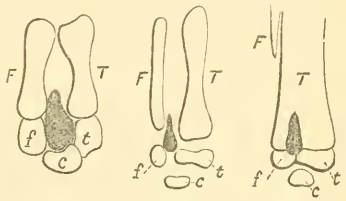

Fig. 6. Fig. 7. Fig. 8.

The *intermedium* in the three figures is represented black.

Fig. 6. Representing lower portion of leg of *Salamandra maculosa*, copied from Gegenbaur, with distal tarsals omitted.

Fig. 7. *Spizella socialis* copied from fig. 1, plate iv, of this paper, with *intermedium* introduced.

Fig. 8. Ideal figure showing true position of *intermedium* in relation to proximal tarsal bones.

F. Fibula. *T. Tibia.*
f. fibulare. *t. tibiale.*
c. centrale.

To show still more plainly the reasons for believing that the pretibial bone of Wyman represents the *intermedium*, the following diagrams are presented. The *intermedium* is represented black. Figure 6 represents the *intermedium* and its associate tarsals in relation to the tibia and fibula of *Salamandra maculosa*, after Gegenbaur.

Figure 7 represents the tarsus of an embryo bird, with the pretibial bone introduced, bearing the same relation that it afterwards does to its own tarsals; and figure 8 represents the pretibial bone and its actual relation to the two tarsals, as seen in Professor Wyman's oldest specimen, the tibia now having widened so as to include the two tarsals within its lateral boundaries, and consequently including the pretibial bone also. That the tibia widens at its distal extremity in that way, so as to equal in width not only the two tarsals, but the three metatarsals, may be seen by referring to plate IV; and indeed to suppose that it would do so is reasonable, since the excessive reduction of the fibula naturally enhances the greater proportionate development of the tibia; and by this excess of growth, the pretibial bone, or intermedium, finds its anomalous position in front of the tibia.

In connection with this elongated *intermedium*, it is interesting to note that in certain lizards where the intermedium is absent, the *centrale* takes on the elongated and slender form, and is wedged between the other tarsals.

If further investigation should prove the correctness of this interpretation, we have an interesting stage in the conditions of this bone represented, namely, that in birds the *intermedium* is at first a separate bone, as in the lower reptiles, but finally it anchyloses with the astragalus, as in higher vertebrates, thus proving the correctness of Gegenbaur's statement that the astragalus of higher vertebrates represents the *tibiale* and *intermedium* connate.

Thus we must recognize in birds the presence of four tarsal bones, and at least four carpal bones.

Concluding Observations. — At an early stage of the embryo the leg and the wing are almost precisely alike, and even after the principal bones have made their appearance the two appendages are remarkably alike in the form and proportion of their parts. This similarity was noticed by

Agassiz a long time ago, as well as the fact that in the embryo robin, the toes are webbed. In the early embryo the toes are always webbed, and for a long time in the embryo all the toes point forward; these are two characters highly characteristic of lower groups of birds. The turning back of the first toe is a subsequent modification.

The first metatarsal appears last in development. The phalanges of the third and fourth toes appear first, and the others in regular succession. The phalanges of the foot appear before those of the hand.

The metacarpals and phalanges are widely separated in the early embryo, and were it possible for the wing at this stage to make a track in the mud, the impression would be like that made by a tridactyle foot. In fact it is a tridactyle foot at this stage. The metatarsals are also separated at the same stage, but not so widely as the metacarpals.

There is a difference of opinion among anatomists in their interpretation of the fingers of the wing. Gegenbaur, Huxley, Rolleston and others, regard the marginal finger on the radial side as representing the first finger, or pollex, while Wyman, Owen and Coues, believe this digit to represent the index, or second finger. It seems more reasonable to believe that this latter interpretation is right; for when the number of fingers or toes is reduced in Mammalia and Reptilia, they are always taken away from the sides of the member, the thumb first disappearing and then the little finger.

If we compare the leg and wing of *Spizella* (figs. 1 and 32, pl. IV and V) we shall see that in this early stage there are but three metatarsals and three metacarpals, and it seems reasonable to compare them together.

As the first toe appears much later and is reduced to two phalanges, and has its metatarsal also greatly reduced, and as at the stage just cited the first toe is represented only by a few granules, it seems natural to infer that in the wing, the first finger never makes its appearance.

In regard to the reptilian characters in birds, it seems that a nearer relation between birds and pterosaurians can be established, with the additional carpals pointed out in this paper. At least one of the characters for separating the pterosaurians from the birds, as given by Owen, fails in the light of these distal carpals.

Owen says, in his "Fossil Reptiles of the Liassic Formation,"* that:—

"A carpus with one large and one small bone in a proximal row, and with a second large, and at least one small one in a distal row, is another character by which the pterosauria manifest their closer affinity to reptiles than to birds." Now this is precisely the character of all those birds thus far examined.

EXPLANATION OF THE PLATES.

Plate IV. THE TARSUS AND EMBRYOS.

In every case the right leg and right wing are represented. For want of room on the plates I have been compelled to leave out the humerus and femur in most of the figures given.

All the embryos are represented of natural size, and by referring to them, an approximate idea may be formed of the size of the appendage drawn, as well as the age and condition of the embryo.

Reference to the embryo preceded by the initial E, follows explanation of the figure, thus: Fig. 1, *Spizella socialis*. E. 18.

Fig. 1. *Spizella socialis*. E. 18.

The three bones separate, the *fibulare* being at the end of the *fibula*. The 2d, 3d and 4th metatarsals not complete, while the 1st metatarsal appears only as a few granules.

Fig. 2. *Spizella socialis*. E. 19.

Tarsal joint appearing, in separation of cartilage between proximal and distal tarsal bones.

Fig. 3. *Turdus fuscescens*. E. 21.

The tarsals separate. The distal end of tibia widening so as to include the proximal tarsals.

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* Palæontographical Soc., Vol. XXIII. 1869.

Fig. 4. *Turdus fuscescens.* Embryo not given.

A later stage in which the proximal tarsals have already united with the tibia, and the distal tarsal has not yet united with the metatarsals.

Fig. 5. *Turdus fuscescens.*

Another view of the same.

Fig. 6. *Tyrannus Carolinensis.* E. 23.

The *tibiale* and *fibulare* united with tibia, the *centrale* still free.

Fig. 7. *Dendrœca æstiva.* E. 24.

The two proximal tarsals united. The *centrale* very large and capping the three metatarsals.

Fig. 8. *Dendrœca æstiva.*

Another view of the same, showing the tarsal bones more distinctly.

Fig. 9. *Dendrœca æstiva.*

Another view of same, showing *centrale* capping the metatarsals.

Fig. 10. *Quiscalus versicolor.* E. 25.

The *tibiale* and *fibulare* united, but not yet anchylosed to the tibia. The *centrale* still free.

Fig. 11. *Quiscalus versicolor.*

An enlarged view of the tarsus.

Fig. 12. *Sialia sialis.* E. 31.

The proximal tarsals united with the tibia. The distal tarsal united with the fourth metatarsal.

Fig. 13. *Sialia sialis.*

Another view of the same.

Fig. 14. *Cotyle riparia.* E. 27.

A considerably advanced stage in which the three tarsal bones are distinctly separate.

Fig. 15. *Hirundo lunifrons.* E. 30.

The *tibiale* and *fibulare* about uniting. The *centrale* already blended with third metatarsal.

Fig. 16. *Tringoides macularius.* E. 26.

The *tibiale* and *fibulare* united forming an hour-glass shaped bone. The *centrale* flattened and capping the metatarsals but not yet united with them.

Fig. 17. *Turdus migratorius.*

Posterior portion of early embryo, showing the leg as a simple fin, and caudal vertebræ.

Fig. 18. *Spizella socialis.*
19. " "
20. " "
21. *Turdus fuscescens.*
22. *Molothrus pecoris.*
23. *Tyrannus Carolinensis.*
24. *Dendrœca æstiva.*
25. *Quiscalus versicolor.*
26. *Tringoides macularius.*
27. *Cotyle riparia.*
28. " " Several days from the egg.
29. *Tringoides macularius.* Just ready to hatch.
30. *Hirundo lunifrons.*
31. *Sialia sialis.*

EXPLANATION OF LETTERS.

FE. *Femur.*
T. *Tibia.*
F. *Fibula.*
TARSUS. { t. *Tibiale = astragalus.*
f. *Fibulare = calcaneum = os calcis.*
c. *Centrale = navicular = scaphoideum.*
I, II, III, IV. Corresponding *metatarsals.*

Plate V. THE CARPUS.

Fig. 32. *Spizella socialis.* E. 18.

Showing three carpals and three metacarpals. No indication of phalanges.

Fig. 33. *Spizella socialis.* E. 19.

The fourth *carpale* now formed; phalanges also formed, and fingers at this stage widely spread.

Fig. 34. *Spizella socialis.* E. 20.

Third and fourth carpal bones united, and third and fourth metacarpals united at distal and proximal ends.

Fig. 35. *Spizella socialis.*

Several days from the egg, and nearly capable of flight.

Fig. 36. *Turdus fuscescens.* E. 21.

Showing four carpals.

Fig. 37. *Turdus fuscescens.*

A slightly more advanced stage, showing the third and fourth carpal bones about uniting. The fourth *carpale* sending out a process to third metacarpal. The *ulnare* apparently uniting with *ulna*.

Fig. 38. *Turdus fuscescens.*

The same *carpus* under slight pressure. The *ulnare* separate again.

Fig. 39. *Quiscalus versicolor.* E. 25.

Showing the minute third *carpale* and the elongated *ulnare*.

Fig. 40. *Molothrus pecoris.* E. 22.

The third and fourth *carpale* united.

Fig. 41. *Sialia sialis.*

Third and fourth *carpale* about uniting, and fourth *carpale* sending out peculiar process to third metacarpal.

Fig. 42. *Sialia sialis.* E. 31.

A slightly more advanced stage, in which the distal carpals and base of metacarpals are all united.

Fig. 43. *Cotyle riparia.* E. 27.

Anchylosis far advanced. *Ulnare* supposed to have united with ulna.

Fig. 44. *Dendrœca æstiva.* E. 24.

Ulnare supposed to have united with the ulna. The carpal marked *i*, supposed to be intermedium. Third and fourth *carpale* united.

Fig. 45. *Hirundo lunifrons.* E. 30.

The four carpals all separate.

Fig. 46. *Tyrannus Carolinensis.* E. 23.

Showing excessively long *radiale*.

Fig. 47. *Tyrannus Carolinensis.*

Another specimen under pressure, with a new carpal? supposed to be *centrale*.

Fig. 48. *Tyrannus Carolinensis.*

Another specimen under pressure, in which the long *ulnare* readily separates, leading to the supposition that the second *carpale* is here present.

The peculiar form of *ulnare* in *Tyrannus*, fig. 47, is seen also in *Molothrus* and *Sialia*, figs. 40, 42 and 43.

EXPLANATION OF LETTERS.

H. *Humerus.*
U. *Ulna.*
R. *Radius.*
CARPUS.
- u. *Ulnare* = *cuneiform.*
- r. *Radiale* = *scaphoid* = *naviculare.*
- c. *Centrale* = *central.*
- i. *Intermedium* = lunar.
- z. Second *carpale* = *trapezoid.*
- 3. Third *carpale* = *magnum.*
- 4. Fourth *carpale* = *unciform.*

II, III, IV. Corresponding *metacarpals.*

IX. — *On the Systematic Arrangement of North American Terrestrial Mollusks.*

BY THOMAS BLAND AND W. G. BINNEY.

Read January 29, 1872.

SINCE the publication of our work on the Land Mollusks of North America,* we have had the opportunity of examining the animals and the lingual dentition of many additional American, as well as numerous foreign species. We have also carefully studied the various systems of classification which have been proposed both here and abroad. The result of our researches is a considerable change in our views regarding the classification of terrestrial mollusca. Such of these changes as relate to the American families, we purpose stating here, referring always to the page of our work containing the description or statement to be modified.

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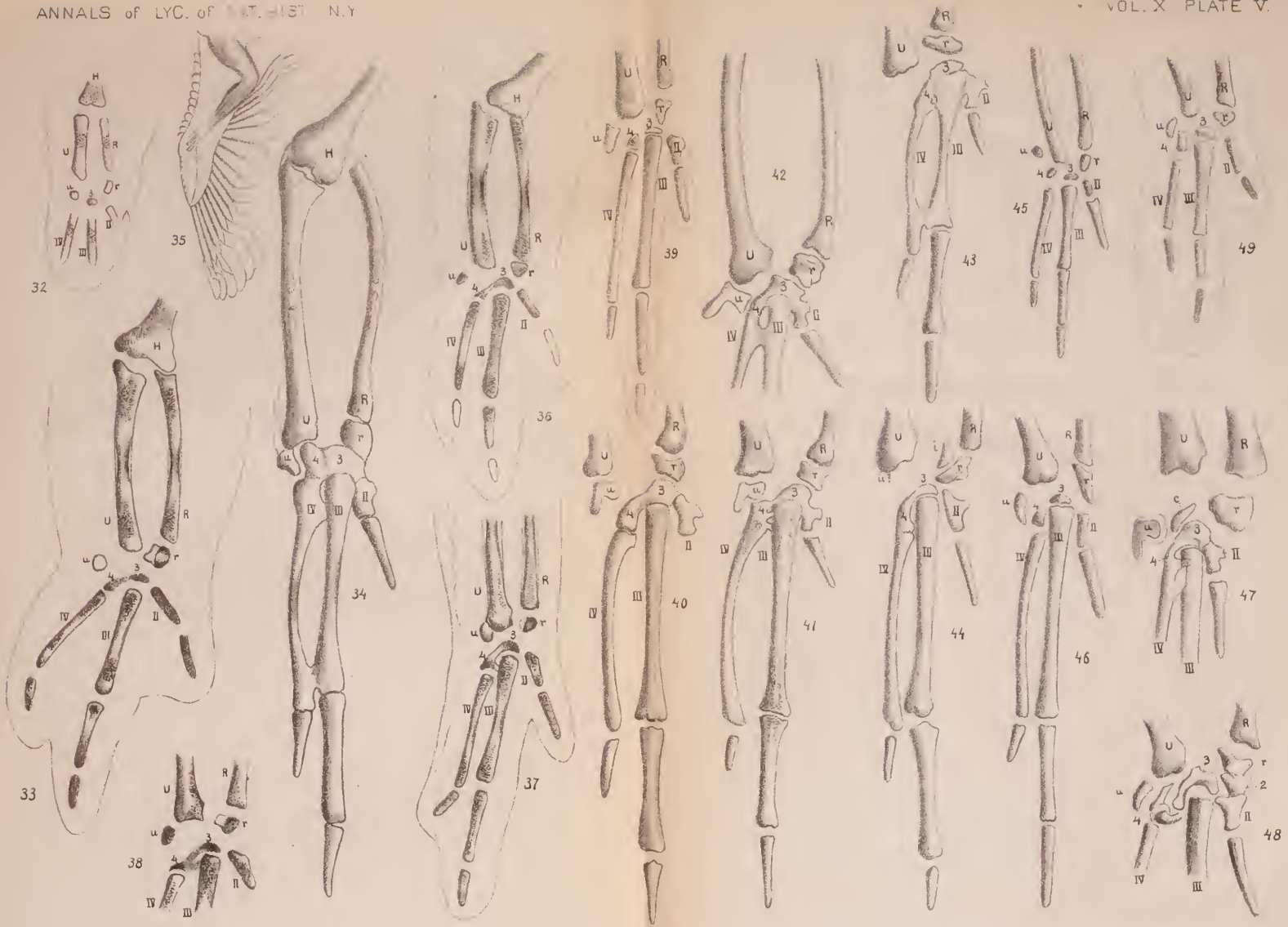
*Land and Fresh-water Shells of North America, Part I. Smithsonian Institution, Feb., 1869.

MORSE ON THE TARSAL AND CARPAL BONES OF BIRDS

Edward S. Morse Del et Lith.

A. Trochsler & Co Lith. Boston



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